VII

REMARKS ON THE COMPASS IN AËRONAUTICS.

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The few remarks which I am able to contribute to the discussion of the papers we have just had the pleasure of listening to, relate to the use of the compass in aërial navigation.

The recent great progress in aëronautical art and in the construction of ships to navigate the air, have called renewed attention to the importance of perfecting the magnetic compass used in steering the craft, and to the need of studying the "vagaries of the fickle needle." Just as in ocean navigation, it has become necessary in aërial navigation, though not yet to the same degree of refinement as in ocean work, to determine the effects on the compass of the magnetic materials used in the construction and in the equipment of the aircraft. The airship-compass must, accordingly, be compensated, and allowance for any outstanding errors must be made in steering a course with it.

The satisfactory solutions of the various problems are especially difficult for the heavier-than-air type of airship. One of the chief points of difference between the aëroplane-compass and the ocean-ship-compass consists in the form of damping device (horse-hair packing, for example) which must be used to overcome, as well as possible, the very excessive vibration caused by the engine driving the aëroplane.

Besides the so-called "magnetic-deviation errors" of the compass, arising from the magnetic materials in the vicinity of the compass, there are other errors which make themselves seriously felt only, however, while the aëroplane is turning. The latter are called "dynamic-deviation errors"; their magnitude depends upon the tilt of the aëroplane, the magnetic dip, and the heading or course of the airship.

When the aëroplane is turning, it is tilted towards the center of

the circle described by it, the tilt becoming greater, of course, with the speed of turning or with the decrease of radius of the circle. Everything movable which was at rest in the aëroplane during straight-line uniform flight under the action of gravity alone is still at rest relative to the aëroplane as it tilts on the turn, but now, everything is at rest under the action of the resultant of gravity and centrifugal accelerations. The compass card, which was horizontal during rectilinear flight, is now tilted with the aëroplane and, consequently, partly turned in the terrestrial magnetic field. The vertical component of the earth's magnetic field, which was normal to the card in its level position in rectilinear flight and which, consequently, had then no directive effect, now has a component in the plane of the card and normal to the magnetic axis which tends to produce the "dynamic deviation." The horizontal component of the earth's magnetic field also plays a part in this kind of deviation.

According to some recent investigations in England by S. G. Starling,[1] when the angle of tilt of the aëroplane approaches the complement of the magnetic dip, which for Philadelphia would mean a tilt of about 19°, the dynamic deviations of the compass, if, for example, the course steered be an easterly one, may increase to nearly 90°. And if the tilt of the aëroplane exceeded 19° the direction of the compass on the course stated would even be reversed.

While the dynamic deviations may be large during turns of the aëroplane, yet they disappear, practically, when straight flight is resumed. We, therefore, question the desirability of adopting the movable compensating devices, suggested by Starling, which while effective during aëroplane-turns, might introduce magnetic deviations of a more permanent character during the more usual straight flights. If his devices are used, they will require careful control.

In connection with the use of the compass in aërial navigation, an interesting scientific question comes up as to the change of the earth's magnetic field, or of the magnetic elements with altitude above the surface. Magnetic experiments of this nature were made in balloons by Gay Lussac and Biot in 1804 which were repeated, with more success, a half century later by Glaisher. The available

[1] "The Equilibrium of the Magnetic Compass in Aëroplanes," *Phil. Mag.*, London, Vol. 32, November, 1916 (461–476).

observations to date do not possess, however, the requisite refinement, and it is hoped that some day a non-magnetic airship and the necessary instrumental appliances will be available for conducting a magnetic survey of the aërial regions in the same manner as that employed in the ocean-magnetic survey of the non-magnetic ship, the *Carnegie*.

Referring to the possible scientific work for airships, it will be of interest to recall that the first scientific aërological observations in a balloon were made in 1784 by an American physician, Dr. John Jeffries, a graduate of Harvard College, residing at the time in London. Dr. Jeffries presented a printed copy of the extremely interesting narrative on his two aërial voyages[2] to Benjamin Franklin, as also a manuscript copy; both are now in the possession of the American Philosophical Society. Other aëronautical papers and letters of historical interest will be found among the magnificent collection of "Frankliniana," belonging to the Society.

[2] In the second of these voyages, made on January 7, 1785, the English Channel was successfully crossed for the first time by aërial flight.